

ACCOMMODATING INTRAOCULAR LENS

BACKGROUND AND SUMMARY OF THE INVENTION

The invention relates generally to intraocular lenses for the human eye and, more particularly, to intraocular lenses that change in refractive power (i.e. "accommodate") in response to eye muscle movement to focus on objects at different distances as viewed from the viewer.

FIGS. 1 through 4 illustrate the accommodation function of a normal, natural human eye, with FIG. 1 showing a human eye in cross-section. The eye structure includes a cornea 13, an iris 16, a ciliary body 17, suspensory ligaments or zonules of zinn 18, a crystalline lens 19 surrounded by a capsular bag 20, and a retina 27. The ciliary body 17 includes muscle tissue, which controls the focal length of the lens 19. When individual circumferential muscle fibers 21 of the ciliary body 17 relax (i.e., when the dimensions 23 increase), the aperture diameter 25 within the ciliary body 17 increases, as shown in FIGS. 2A and 2B.

As shown in FIGS. 3A and 3B, this increase in aperture diameter puts tension on the zonules 18, which in turn stretch the crystalline lens 19, causing the lens 19 to assume elongated shape 19E. the elongated lens 19E has a refractive power suitable for focusing distant objects upon the retina 27. When it is necessary to focus nearby objects, the muscle fibers 21 of ciliary body 17 contract, decreasing the aperture diameter 25 shown in FIG. 2A. In response to this contraction, the inherent elasticity of the lens 19 causes it to contract to the unstretched shaped shown in FIG. 3A. This ability of the human optical system to change the shape of the lens 19 (and thus the refractive power) in order to focus on either distant or nearby objects is called "accommodation".

The lens 19 of the human eye can, however, suffer disease, such as a cataract, in which case surgical removal of the lens 19 may be necessary. After removal, the natural lens 19 can be replaced by an artificial lens 32 shown in FIG. 4, which is termed an intraocular lens (IOL). One type of IOL 32 is shown in FIGS. 5A and 5B. The lens 32 is supported by haptics 36, which rest generally at points 37 in FIG. 4 after implantation in the eye.

The IOL 32 restores much of the visual acuity of the eye, but has the characteristic of properly focusing only images of objects 34 in FIG. 4 which are within the depth of field 39 of the focusing system, said system being comprised of the IOL 32 and the cornea 13. Other objects, such as the object 41 located in the far field 43, are not in focus, and thus appear blurred. It is also possible, instead, for the focusing system to properly focus objects in the far field 43 but not in the near field 39. The accommodation necessary to selectively focus on both near and far objects, formerly provided by the crystalline lens 19, has thus been reduced or lost.

It is therefore highly desirable to restore accommodation in order to allow the patient with an IOL to selectively focus objects located at all distances. Thus one of the primary objects of the present invention is to provide an improved intraocular lens that can focus objects located at different distances upon the retina, depending upon the relaxed or contracted state of the ciliary body muscles.

One form of the invention comprises a replacement lens for the human eye, which changes in focal length as the ciliary muscle contracts and relaxes.

According to the present invention, an accommodating intraocular lens apparatus includes a lens member having a flexible portion and a relatively rigid portion, with a chamber therebetween. The apparatus also includes an accommodation provision for changing the shape or position of the flexible lens member in response to muscle movement of the eye. Such accommodation feature provides the mechanism to change the refractive characteristics of the flexible lens member and thus allows the intraocular lens patient to focus on objects at varying distances much in the same way as did the patient's natural crystalline lens. In the preferred embodiments, such accommodation capability is provided by way of a hydraulic or other fluid system incorporated into the intraocular lens apparatus for selectively pressurizing and de-pressurizing a fluid-filled (liquid or gaseous) chamber defined by the flexible lens member and a relatively rigid supporting member in order to selectively vary the refractive powers or characteristics of the overall lens system.

Additional objects, advantages and features of the present invention will become apparent from the following description and appended claims taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 diagrammatically illustrates a human eye in cross-section.

FIGS. 2A and 2B diagrammatically illustrate dilation of the ciliary body of the eye.

FIGS. 3A and 3B diagrammatically illustrate how the dilation shown in FIG. 2B stretches the crystalline lens and changes its focal length.

FIG. 4 illustrates an intraocular lens that can be used to replace the natural lens 19 in FIG. 1.

FIGS. 5A and 5B are enlarged views of a common type of intraocular lens.

FIG. 6 illustrates an exploded view of an intraocular lens apparatus according to one form of the invention.

FIG. 7 illustrates a detailed view of the intraocular lens apparatus of FIG. 6 shown in cross-section.

FIGS. 8A and 8B illustrate the change in shape of the chamber of the lens apparatus shown in FIG. 7, which occurs during use of the invention.

FIG. 9 illustrates one form of the intraocular lens apparatus of the present invention.

FIG. 10 illustrates another form of the intraocular lens apparatus of the present invention implanted within the ciliary body of the eye.

FIG. 11 illustrates a preferred form of the present invention, including pressure sources used to inflate flexible bladders, which contact or expand in response to action of the ciliary body.

FIG. 12 shows in schematic form how the ciliary body compresses one pair of the bladders shown in FIG. 11.

FIG. 13 shows the apparatus of FIG. 11 in perspective, cut-away form.

FIG. 14 is a view similar to that of FIG. 10, but illustrating still another form of the intraocular lens apparatus of the present invention.

FIG. 15 is a partial detail view of the lens apparatus of FIG. 14, illustrating a hollow haptic member.